

rate of 3 units/s. How fast is  $z$  changing at this instant? Is  $z$  increasing or decreasing?

11. The minute hand of a certain clock is 4 in long. Starting from the moment when the hand is pointing straight up, how fast is the area of the sector that is swept out by the hand increasing at any instant during the next revolution of the hand?
12. A stone dropped into a still pond sends out a circular ripple whose radius increases at a constant rate of 3 ft/s. How rapidly is the area enclosed by the ripple increasing at the end of 10 s?
13. Oil spilled from a ruptured tanker spreads in a circle whose area increases at a constant rate of  $6 \text{ mi}^2/\text{h}$ . How fast is the radius of the spill increasing when the area is  $9 \text{ mi}^2$ ?
14. A spherical balloon is inflated so that its volume is increasing at the rate of  $3 \text{ ft}^3/\text{min}$ . How fast is the diameter of the balloon increasing when the radius is 1 ft?
15. A spherical balloon is to be deflated so that its radius decreases at a constant rate of 15 cm/min. At what rate must air be removed when the radius is 9 cm?
16. A 17-ft ladder is leaning against a wall. If the bottom of the ladder is pulled along the ground away from the wall at a constant rate of 5 ft/s, how fast will the top of the ladder be moving down the wall when it is 8 ft above the ground?
17. A 13-ft ladder is leaning against a wall. If the top of the ladder slips down the wall at a rate of 2 ft/s, how fast will the foot be moving away from the wall when the top is 5 ft above the ground?
18. A 10-ft plank is leaning against a wall. If at a certain instant the bottom of the plank is 2 ft from the wall and is being pushed toward the wall at the rate of 6 in/s, how fast is the acute angle that the plank makes with the ground increasing?
19. A softball diamond is a square whose sides are 60 ft long. Suppose that a player running from first to second base has a speed of 25 ft/s at the instant when she is 10 ft from second base. At what rate is the player's distance from home plate changing at that instant?
20. A rocket, rising vertically, is tracked by a radar station that is on the ground 5 mi from the launchpad. How fast is the rocket rising when it is 4 mi high and its distance from the radar station is increasing at a rate of 2000 mi/h?
21. For the camera and rocket shown in Figure 3.7.4, at what rate is the camera-to-rocket distance changing when the rocket is 4000 ft up and rising vertically at 880 ft/s?
22. For the camera and rocket shown in Figure 3.7.4, at what rate is the rocket rising when the elevation angle is  $\pi/4$  radians and increasing at a rate of 0.2 radian/s?
23. A satellite is in an elliptical orbit around the Earth. Its distance  $r$  (in miles) from the center of the Earth is given by

$$r = \frac{4995}{1 + 0.12 \cos \theta}$$

where  $\theta$  is the angle measured from the point on the orbit nearest the Earth's surface (see the accompanying figure).

- (a) Find the altitude of the satellite at *perigee* (the point nearest the surface of the Earth) and at *apogee* (the point farthest from the surface of the Earth). Use 3960 mi as the radius of the Earth.
- (b) At the instant when  $\theta$  is  $120^\circ$ , the angle  $\theta$  is increasing at the rate of  $2.7^\circ/\text{min}$ . Find the altitude of the satellite and the rate at which the altitude is changing at this instant. Express the rate in units of mi/min.



Figure Ex-23

24. An aircraft is flying horizontally at a constant height of 4000 ft above a fixed observation point (see the accompanying figure). At a certain instant the angle of elevation  $\theta$  is  $30^\circ$  and decreasing, and the speed of the aircraft is 300 mi/h.
  - (a) How fast is  $\theta$  decreasing at this instant? Express the result in units of degrees/s.
  - (b) How fast is the distance between the aircraft and the observation point changing at this instant? Express the result in units of ft/s. Use  $1 \text{ mi} = 5280 \text{ ft}$ .

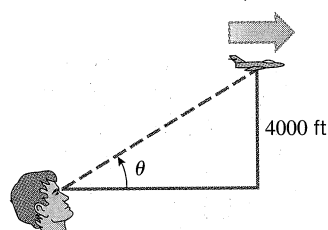


Figure Ex-24

25. A conical water tank with vertex down has a radius of 10 ft at the top and is 24 ft high. If water flows into the tank at a rate of  $20 \text{ ft}^3/\text{min}$ , how fast is the depth of the water increasing when the water is 16 ft deep?
26. Grain pouring from a chute at the rate of  $8 \text{ ft}^3/\text{min}$  forms a conical pile whose altitude is always twice its radius. How fast is the altitude of the pile increasing at the instant when the pile is 6 ft high?
27. Sand pouring from a chute forms a conical pile whose height is always equal to the diameter. If the height increases at a constant rate of 5 ft/min, at what rate is sand pouring from the chute when the pile is 10 ft high?
28. Wheat is poured through a chute at the rate of  $10 \text{ ft}^3/\text{min}$ , and falls in a conical pile whose bottom radius is always half

the altitude. How fast will the circumference of the base be increasing when the pile is 8 ft high?

29. An aircraft is climbing at a  $30^\circ$  angle to the horizontal. How fast is the aircraft gaining altitude if its speed is 500 mi/h?
30. A boat is pulled into a dock by means of a rope attached to a pulley on the dock (see the accompanying figure). The rope is attached to the bow of the boat at a point 10 ft below the pulley. If the rope is pulled through the pulley at a rate of 20 ft/min, at what rate will the boat be approaching the dock when 125 ft of rope is out?

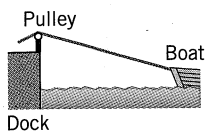


Figure Ex-30

31. For the boat in Exercise 30, how fast must the rope be pulled if we want the boat to approach the dock at a rate of 12 ft/min at the instant when 125 ft of rope is out?
32. A man 6 ft tall is walking at the rate of 3 ft/s toward a streetlight 18 ft high (see the accompanying figure).
- At what rate is his shadow length changing?
  - How fast is the tip of his shadow moving?

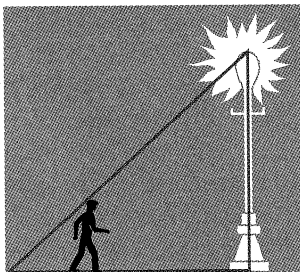


Figure Ex-32

33. A beacon that makes one revolution every 10 s is located on a ship anchored 4 kilometers from a straight shoreline. How fast is the beam moving along the shoreline when it makes an angle of  $45^\circ$  with the shore?
34. An aircraft is flying at a constant altitude with a constant speed of 600 mi/h. An anti-aircraft missile is fired on a straight line perpendicular to the flight path of the aircraft so that it will hit the aircraft at a point  $P$  (see the accompanying figure). At the instant the aircraft is 2 mi from the impact point  $P$  the missile is 4 mi from  $P$  and flying at 1200 mi/h. At that instant, how rapidly is the distance between missile and aircraft decreasing?

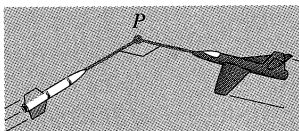


Figure Ex-34

35. Solve Exercise 34 under the assumption that the angle between the flight paths is  $120^\circ$  instead of the assumption that the paths are perpendicular. [Hint: Use the law of cosines.]
36. A police helicopter is flying due north at 100 mi/h and at a constant altitude of  $\frac{1}{2}$  mi. Below, a car is traveling west on a highway at 75 mi/h. At the moment the helicopter crosses over the highway the car is 2 mi east of the helicopter.
- How fast is the distance between the car and helicopter changing at the moment the helicopter crosses the highway?
  - Is the distance between the car and helicopter increasing or decreasing at that moment?
37. A particle is moving along the curve whose equation is

$$\frac{xy^3}{1+y^2} = \frac{8}{5}$$

Assume that the  $x$ -coordinate is increasing at the rate of 6 units/s when the particle is at the point  $(1, 2)$ .

- At what rate is the  $y$ -coordinate of the point changing at that instant?
  - Is the particle rising or falling at that instant?
38. A point  $P$  is moving along the curve whose equation is  $y = \sqrt{x^3 + 17}$ . When  $P$  is at  $(2, 5)$ ,  $y$  is increasing at the rate of 2 units/s. How fast is  $x$  changing?
39. A point  $P$  is moving along the line whose equation is  $y = 2x$ . How fast is the distance between  $P$  and the point  $(3, 0)$  changing at the instant when  $P$  is at  $(3, 6)$  if  $x$  is decreasing at the rate of 2 units/s at that instant?
40. A point  $P$  is moving along the curve whose equation is  $y = \sqrt{x}$ . Suppose that  $x$  is increasing at the rate of 4 units/s when  $x = 3$ .
- How fast is the distance between  $P$  and the point  $(2, 0)$  changing at this instant?
  - How fast is the angle of inclination of the line segment from  $P$  to  $(2, 0)$  changing at this instant?
41. A particle is moving along the curve  $y = x/(x^2 + 1)$ . Find all values of  $x$  at which the rate of change of  $x$  with respect to time is three times that of  $y$ . [Assume that  $dx/dt$  is never zero.]
42. A particle is moving along the curve  $16x^2 + 9y^2 = 144$ . Find all points  $(x, y)$  at which the rates of change of  $x$  and  $y$  with respect to time are equal. [Assume that  $dx/dt$  and  $dy/dt$  are never both zero at the same point.]
43. The *thin lens equation* in physics is

$$\frac{1}{s} + \frac{1}{S} = \frac{1}{f}$$

where  $s$  is the object distance from the lens,  $S$  is the image distance from the lens, and  $f$  is the focal length of the lens. Suppose that a certain lens has a focal length of 6 cm and that an object is moving toward the lens at the rate of 2 cm/s. How fast is the image distance changing at the instant when the object is 10 cm from the lens? Is the image moving away from the lens or toward the lens?